

Nepheloid Layer Measurements and Floc Model for OASIS

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LONG-TERM GOALS

The long-term goal of our research is to improve fundamental understanding and numerical representation of coastal sediment-transport processes. USGS scientists have participated in the ONR STRESS and EuroSTRATAFORM projects, and the Ripples and Tidal-Flats DRIs, where our goal has been to improve quantitative models describing the relationships among meteorological and oceanographic forcing, freshwater influx, particle resuspension, and transport and accumulation of sediment in the coastal ocean. We are participating in the Optics Acoustics and Stress In Situ (OASIS) project with many of the same goals, with additional focus on the interaction between bed and suspended sediments and the influence of fine sediment and flocs on optical properties in the water column. We are funded through the U. S. Geological Survey (USGS) Coastal and Marine Geology Program to continue work begun during a National Oceanographic Partnership Program (NOPP)-funded partnership to develop a community sediment-transport modeling system (CSTMS) based on the Regional Ocean Modeling System (ROMS). Quantitative understanding of sedimentary processes is important to the Navy because these processes determine environmental conditions in coastal regions, including current speeds, turbulence, water-column turbidity, and bottom acoustic properties. These processes are also of great interest to geologists, coastal engineers, and coastal resource managers because they drive sediment transport, coastal erosion, and coastal ecosystems.

OBJECTIVES

The scientific objectives of our proposal are as follows:

- Implement a simplified floc model into a 3D, regional-scale numerical model for circulation and sediment transport (ROMS/CSTMS).
- Measure detailed profiles of suspended sediment concentration and particle size in the bottom boundary layer (~bottom two meters), along with physical measurement of waves and currents.

APPROACH

Our approach is to implement a simplified floc model and test it against OASIS field data. The model is intended to capture the key components of the aggregation and disaggregation dynamics that affect water-column particle distributions and be efficient enough to run regional-scale simulations. The

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model has been developed in collaboration with co-PIs Hill, Milligan, and Boss, and includes components of the Winterwerp et al. (2006) model.

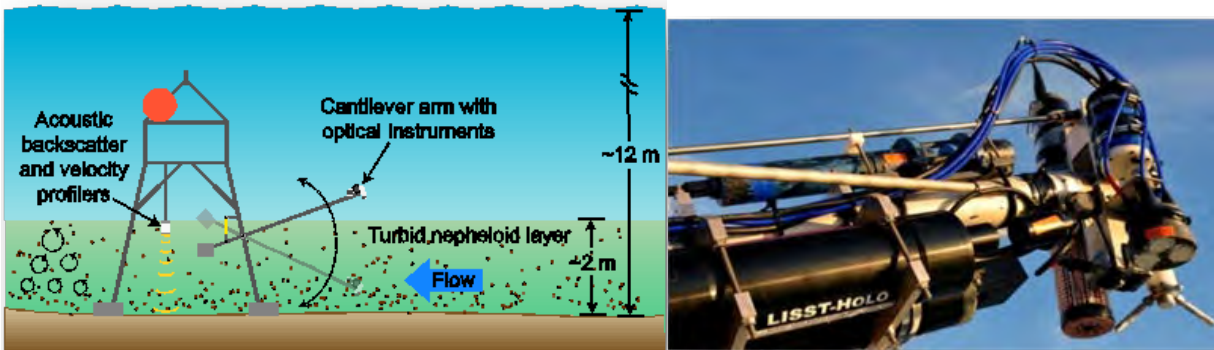


Figure 1. Left: Schematic illustration of proposed tripod with optical instruments on cantilever arm for profiling particle distributions in the bottom boundary layer (illustration by P. Dickhudt, USGS). Right: Photo of the instrument package on the end of the arm during deployment at MVCO in September (photo by Dann Blackwood, USGS).

The practical test of the model is skill in producing profiles of particle distributions that can be compared with optical and acoustic measurements. Profiles provide a particularly demanding test because there are usually steep gradients in Reynolds stress, diffusivity, suspended mass, and particle size in the bottom few meters, and it is more difficult for a model to replicate the profiles than reproduce measurements at a fixed elevation. The striking nepheloid bottom layer sometimes seen by divers is an example.

Although acoustic profiles are available, there are few detailed profiles of optical properties in the bottom boundary layer. Detailed profiles of particle size and particle concentration, coupled with measurements of temperature, salinity, and turbulence over a range of conditions, will provide new data for the critical evaluation of BBL models for sediment distribution and floc size. We propose to measure profiles of suspended-sediment and optical properties by moving sensors mechanically through the bottom boundary layer.

WORK COMPLETED

We have designed, assembled, and deployed a device for measuring profiles of optical, acoustical, and oceanographic properties in the bottom boundary layer. The profiler uses a screw-driven cantilever arm to move an instrument package from about 0.2 to 2.3 meters above the bed. The end of the arm moves at about 12 cm/minute, so each profile takes about 17 minutes to complete. This allows profiles to be collected in an interval that is short compared with slowly varying tidal currents and wave conditions, but slowly enough to average out effects of individual waves and turbulence.

We deployed the profiler as part of the OASIS project field experiment in a region of fine sand on the New England inner shelf. The profiler is connected to the 12-m node of the Martha's Vineyard Coastal Observatory (MVCO), which makes long-term oceanographic measurements and supplies power and an internet connection to our tripod. On-board computers control the arm motion and provide real-time

data acquisition for several instruments, including an accelerometer; a YSI CTD with pressure, dissolved oxygen, and turbidity sensors; and a LISST-Holo holographic imaging camera. The profiling package on the arm also includes a 20-cm transmissometer, an acoustic Doppler velocimeter, a LISST 100-X laser particle sizer, and an infrared optical backscattering sensor. OASIS co-PI Emmanuel Boss (U. Maine) has installed on our arm a multispectral backscatter sensor with fluorometer and the intake for a pump-sampler that runs water through an absorption/attenuation meter. Several other fixed instruments are mounted at various elevations on the tripod, including five acoustic Doppler current meters, three transmissometers, three optical backscatter sensors, and two CTDs. The elevations and sampling rate of these sensors have been coordinated with OASIS PIs Milligan, Hill, and Traykovski, who have deployed instruments nearby to measure flow, bottom stress, bedform morphology, and floc properties.

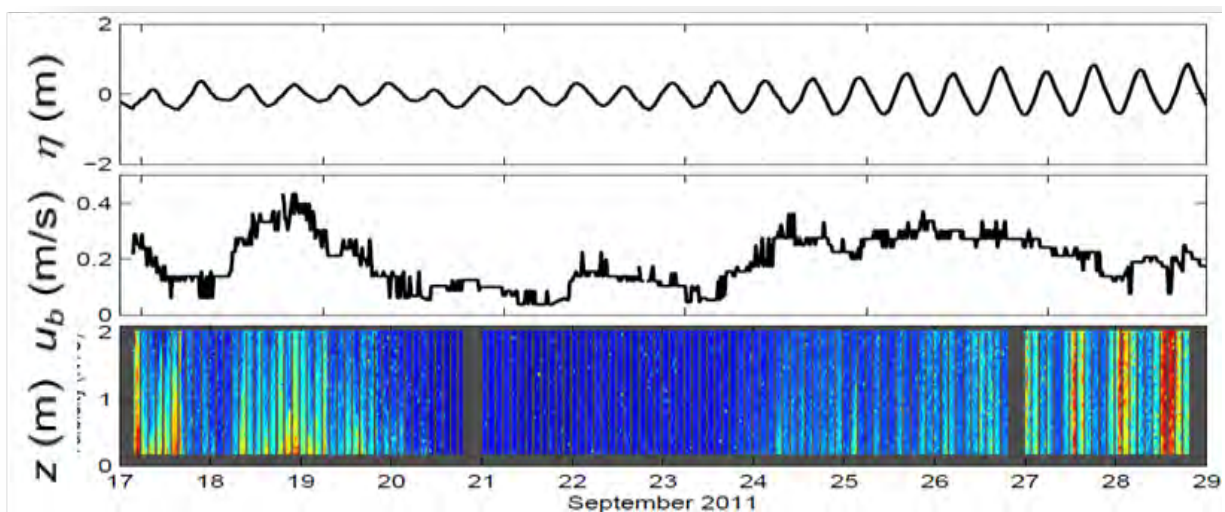


Figure 2. Time series from instruments at the 12-m MVCO site. *Top: tide height from MVCO. Middle: calculated near-bottom wave-orbital velocities based on MVCO wave data. Bottom: profiles of turbidity from an optical sensor (YSI model 6136) on our cantilevered arm. Colors are log-spaced and range from 0.2 to 100 NTU. Gray regions fill short intervals between profiles and longer gaps when the MVCO was powered down for servicing.*

RESULTS

This project has produced a new capability for measuring profiles of optical properties in the bottom boundary layer along with relevant acoustical and physical properties. This is significant because earlier methods were limited in either duration, vertical extent, or resolution. Our method will provide data valuable for evaluating near-bottom conditions and testing numerical models of particle distributions and associated absorption, transmission, and scattering of both light and sound resulting from resuspension and settling, and aggregation/disaggregation, and settling.

IMPACT/APPLICATIONS

The measurements we are making will allow more critical evaluation for models of particle aggregation, acoustics, and optics than previously possible because the profiles are being made

continuously with the same sensors and include co-located contemporaneous measurements of many key properties. This will lead to better and more complete models for flocs, sediment-transport, and diver visibility.

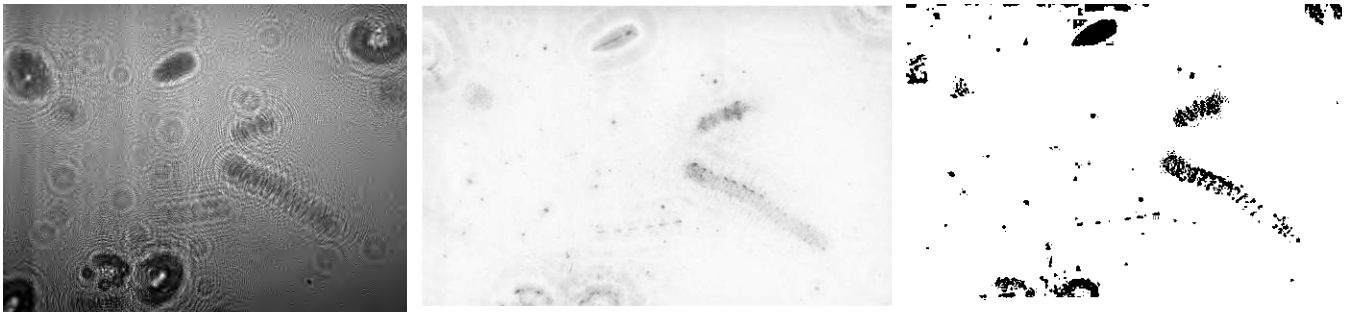


Figure 3. *Images from the Sequoia LISST-Holo mounted on the cantilevered arm. Left: Raw image with diffraction patterns. Middle: Partially processed image showing standard deviation of solutions for various focal planes. Right: Particles resolved by image-processing routines, including flocs, phytoplankton, and zooplankton in the water column, and barnacles growing on the lenses.*

RELATED PROJECTS

Methods and results of this work will inform current and future ONR projects.

REFERENCES

Winterwerp, J.C., Manning, A.J., Martens, C., de Mulder, T. and Vanlede, J., 2006. A heuristic formula for turbulence-induced flocculation of cohesive sediment. *Estuarine, Coastal and Shelf Science*, 68(1-2)195-207.